

Interaction of radiation with matter

Part 2

Interaction of Charged Particles with Matter

Introduction

General

- “The interaction of charged particles with matter” concerns the transfer of energy from the charged particles to the material through which they travel.
- The “charged particles” considered here are:
 - Alpha particles (+2 charge), [alpha particle is nucleus of helium]
 - Beta particles (+ or -1 charge)
 - Photons and neutrons, which have no charge, interact very differently.
- Charged particles passing through matter continuously interact with the electrons and nuclei of the surrounding atoms.
- In other words, alpha and beta particles are continually slowing down as they travel through matter.
- The interactions involve the electromagnetic forces of attraction or repulsion between the alpha or beta particles and the surrounding electrons and nuclei.

Force of the Interaction

The force associated with these interactions can be described by Coulomb’s equation:

$$F = \frac{k q_1 q_2}{r^2}$$

K: is a constant = $9 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$.

q₁: is the charge on the incident particle in Coulombs.

q₂: is the charge on the “struck” particle.

r: is the distance between the particles in meters.

Things to notice about the equation:

- The force increases as the charge increases.
- The force increases as the distance decreases .
- The force can be positive or negative (attractive or repulsive).

Four Types of Charged Particle Interactions

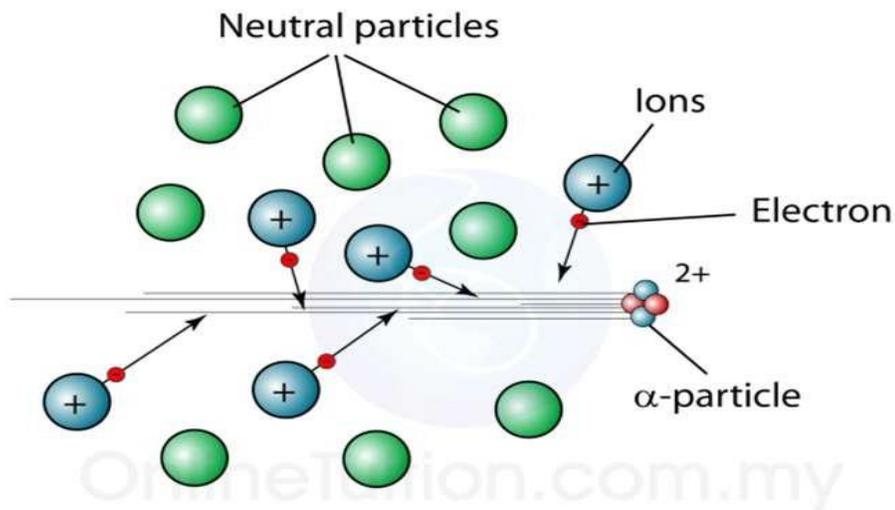
- the four types of interactions are:
 1. Ionization (alphas and betas)
 2. Excitation (alphas and betas)
 3. Bremsstrahlung (primarily betas)
 4. Cerenkov radiation (primarily betas)
- **Ionization is almost always the primary mechanism of energy loss.**

Ionization

- A charged particle (alpha or beta particle) exerts sufficient force of attraction or repulsion to completely remove one or more electrons from an atom.

The energy imparted to the electron must exceed the binding energy of the electron.

- Ionization is most likely to involve atoms near the charged particle's trajectory.
- Each ionization event reduces the charged particle's velocity, i.e., the alpha or beta particles loses kinetic energy.



Alpha particle tends to attract electrons away from nearby molecules, and cause the molecules to become ions

Figure(1): ionization of the alpha particle

- Ionization turns a neutral atom into an ion pair.
- The electron stripped away from the atom is the negative member of the ion pair. It is known as a secondary electron.
- The secondary electron has some, but not much, kinetic energy. Sometimes it has enough energy to ionize additional atoms.

Excitation

- The charged particle (alpha or beta particle) exerts just enough force to promote one of the atom's electrons to a higher energy state (shell).
- Excitation usually occurs farther away from charged particle's trajectory than ionization.
- The excited atom will de-excite and emit a low energy ultraviolet photon.
- Each excitation event reduces the charged particle's velocity.

Bremsstrahlung

- Bremsstrahlung radiation is electromagnetic radiation (photon) that is produced when charged particles are deflected while traveling near an atomic nucleus.
- Bremsstrahlung is almost exclusively associated with electrons (beta particles) because the latter are easily deflected.

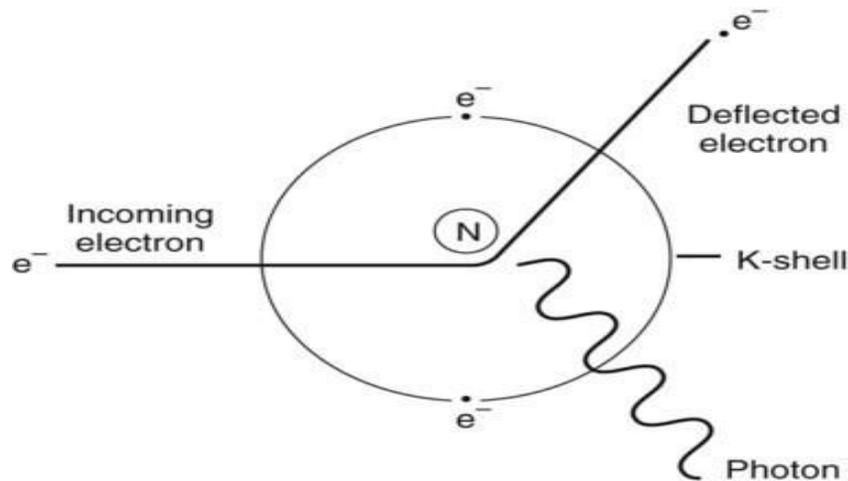


Figure: Bremsstrahlung interaction

Large particles (e.g., alpha particles) do not produce significant bremsstrahlung because they travel in straight lines. Since they aren't deflected to any real extent, bremsstrahlung production is inconsequential.

Cerenkov Radiation

- Cerenkov radiation: Is the blue light emitted by charged particles that travel through a transparent medium (e.g., water) faster than the speed of light in that medium.
- The production of Cerenkov radiation is essentially limited to high energy (i.e., fast) beta particles and electrons.

